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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Numerical simulation of flow, H_2SO_4 cycle and new particle formation in the CERN CLOUD chamber" *by* J. Voigtländer et al.

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First of all we would like to thank referee 2 for his valuable comments and suggestions. In the following the comments will be addressed and discussed.

"Title: I am not fully satisfied with the title of this paper. The whole idea of the paper is to simulate the influence of mixing conditions in the chamber, yet mixing is not mentioned in the title at all. Saying that the paper simulates new particle formation gives also a wrong impression about the contents of the paper: in this regard, the paper investigates whether mixing conditions might significantly affect new particle formation in the chamber."

We followed the suggestion of the referee and changed the title of the manuscript

to:
"Numerical simulations of mixing conditions and aerosol dynamics in the CERN CLOUD chamber."

"Introduction: Firstly, in motivating the word, more recent references on the cosmic ray-cloud connections should be included. Secondly, as far as I know, the CLOUD chamber is very useful not only in investigating the influence of cosmic rays, but also because it is a very clean experimental facility for aerosol formation studies. This could be mentioned here."

The introduction has been rewritten following the suggestions of the referee:
"Largest uncertainties in understanding the current climate change are attributed to aerosols and clouds (IPCC2007). These uncertainties partly result from solar-related contributions and require further research. For example, still under discussion are galactic cosmic ray ionization effects on aerosols and clouds (e.g., Carslaw et al., 2002; Enghoff and Svensmark, 2008; Kirkby, 2007; Kulmala et al., 2010; Svensmark and Friis-Christensen, 1997). To investigate quantitatively both, particle nucleation and the effects of ionisation on particle nucleation, the Cosmics Leaving OUtdoor Droplets (CLOUD) project was established. Within this project, experiments are carried out at a large volume cloud chamber (26.1 m^2) located at CERN (Switzerland). The chamber has been carefully designed for carrying out experiments under very clean and thermodynamically stable conditions (Kirkby et al., 2011) and can be exposed a particle beam provided by the CERN Proton Synchrotron (PS) particle accelerator. The particle beam is applied to create ions and to study their effect on aerosol particle formation and on cloud condensation nuclei and ice nuclei activation."

"Section 3.1: I do not understand what the authors mean by the numerical grid in figure 2 (also figure 5) please explain somewhere in the text."

The numerical grid is the calculation domain for the CFD-model. An additional

sentence has been added to the text (section 3.1):
"For the simulations, the geometry of the CLOUD chamber must be discretised on a numerical grid. Subsequently, the fluid and particle dynamics equations are solved on this grid."

"Section 4.1.1: Gaseous sulfuric acid concentration measurements are known to have a relatively large uncertainty. Does this uncertainly play any role in comparing simulations with sulphuric acid measurements, and could it affect the conclusions made in this paper?"

Because the observed short term fluctuations were small, the experimental uncertainty of the gaseous H_2SO_4 concentration measurements does not effect the conclusion of the manuscript. Concerning the question of the referee, we added to the manuscript (section 4.1.1):
"The experimental uncertainties of gaseous H_2SO_4 concentration measurements are about a factor of 2. On the other hand, observed short term fluctuations of the H_2SO_4 concentrations, which represent the combination of instrumental noise and local fluctuations in the small sampling volume, were much smaller (less than 20 percent, see Fig. 6). It can be concluded that the measurement uncertainties might influence the (initial) average H_2SO_4 concentration of the experiment, but did not affect the temporal characteristics of the H_2SO_4 concentrations at the sampling point, as well as the comparison with the modeling data."

"Section 4.1.2: I do not think it is necessary to use a whole paragraph for discussing sulphuric acid diffusion coefficient."

Addressing the comment of the referee, the paragraph was replaced by the following 2 sentences:
"Furthermore, diffusion coefficients of 0.09 $cm^2 s^{-1}$ (H_2SO_4 in air) and 0.06 $cm^2 s^{-1}$ (H_2SO_4 in H_2O) were applied in the simulations (Marti et al., 1997;

Hanson and Eisele, 2000; Brus et al., 2010). These values are comparable to values determined using the methods of Fuller (FSG, Fuller et al., 1966), FSG-LaBas (Lymann, 1993) or Wilcke and Lee (WL, Wilke and Lee, 1955), which give 0.11 $cm^2 s^{-1}$, 0.093 $cm^2 s^{-1}$ and 0.1 $cm^2 s^{-1}$, respectively."

"Other issues:
The authors find a strong influence of the shape of the fan/fans on their simulation results, yet they cannot say which fan shape they should apply in their simulations. Is the sensitivity of the obtained result to the fan shape a real thing, or does emerge from numerical treatment of the problem?"

A 2-dimensional (2-D) simulation, as used for the investigations shown in the manuscript, does not allow a one-to-one description of the fan geometry. The mixing fans are represented by zero thickness layers with a pressure jump dependent on fan speed. The adjustment of the model was done by a comparison with measured velocity profiles. The fan shape therefore emerge from numerical treatment of the problem, as supposed by the referee. It follows that an arc shaped fan blade in the model does not correspond to a arc shaped fan blade in the experimental set up, but means that the fan produces a broad swirl. Parts of the manuscript were rewritten to clarify this issue. Thereby, the detailed discussion of the (unrealistic, since only theoretical) simple flat fan approach was left out. Combined with additionally included experimental data of the current 2-fan configuration, we think the structure and the scientific relevance of the revised manuscript is improved.

"In my opinion, there are too many figures in the paper. Some of the figure could perhaps be combined together (i.e. figures 8-11 could as well be figure 8a to d) or, alternatively, some figures might not be necessary at all."

We followed this suggestion. In the revised version of the manuscript, several figures were combined (e.g., Fig. 8 and Fig. 10, Fig. 13 - Fig. 15).

"The figures plotting curves should preferably be made to look more alike. Now there are at least 2 or 3 different figure formats for such figures. "

We corrected the format of the figures.

"There are a few grammatical mistakes throughout the text. The authors should check out the language carefully when preparing the final version of the paper. "

This was done.

References

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